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TASK FINAL REPORT

on

REVIEW OF R&D ON WATER HYACINTH
UTILIZATION IN THE PHILIPPINE REPUBLIC
(Report No. BCL-OA-TFR-76-9)

by

J. L. Otis and M. E. D. Hillman

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16. Abstracts The operations of a Filipino inventor, Godofredo G. Monsod, Jr., were observed with a view toward determining the technical-economic potential of his hyacinth utilization concepts. Extensive interviews were conducted in the Philippines with Mr. Monsod and his associates, and his company/laboratory facilities were visited. Information and data obtained were subsequently evaluated by Battelle specialists. Subjects of particular interest included (1) water hyacinth harvesting techniques, volumes and costs, (2) hyacinth defibering processes, and (3) uses of hyacinth materials for production of animal feeds, paper fibers, particle boards, acoustic and insulation boards, various vitamins and minerals (especially Vitamin A), food products, pesticides and medicinal and pharmaceutical products. Although the Monsod hyacinth utilization system, as now conceived, would not be appropriate for use in the more industrialized nations such as the United States, it appears that important exploratory research has been conducted to illustrate meaningful end-use applications for water hyacinth-based products. Economic evaluation now needs to be made of these end-use potentials for U.S. conditions.				
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EXECUTIVE SUMMARY

If water hyacinths can be converted into useful products, the market value of these products could offset a portion of the cost of waste water treatment utilizing a hyacinth-based system. Of perhaps greater significance is the possibility of alleviating the problem of disposing of the harvested hyacinths. If the plants can be utilized, a cleaner and more efficient system design could result.

Accordingly, the operations of a Filipino inventor, Godofredo G. Monsod, Jr., were observed with a view toward determining the technical-economic potential of his hyacinth utilization concepts. Extensive interviews were conducted in the Philippines with Mr. Monsod and his associates, and his company/laboratory facilities were visited. Information and data obtained were subsequently evaluated by Battelle specialists.

Subjects of particular interest included (1) water hyacinth harvesting techniques, volumes and costs, (2) hyacinth defibering processes, and (3) uses of hyacinth materials for production of animal feeds, paper fibers, particle boards, acoustic and insulation boards, various vitamins and minerals (especially Vitamin A), food products, pesticides and medicinal and pharmaceutical products.

Mr. Monsod's hyacinth work is based on a cottage industry concept, wherein families would harvest the plants and prepare intermediate products. We believe that the single most important research finding of Mr. Monsod's efforts to date relates to the concept that useful products could be prepared from water hyacinths if the highly fibrous portion of the plant were separated from the other components. Use of such water hyacinth fiber as feedstock for pulp production would probably eliminate several of the problems that have been found to occur when the whole plant is used as a feedstock. Additionally, the defibered portion of the plant could be used as an animal feed protein supplement, because removal of the cellulose fiber would reduce concern about the digestibility of the hyacinth plant materials. Monsod has also made experimental panels of hyacinth-based particle boards which we believe show a reasonable possibility for eventual proof of technical/economic feasibility after completion of an appropriate R&D program.

Although the Monsod hyacinth utilization system, as now conceived, would not be appropriate for use in the more industrialized nations such as the United States, it appears that important exploratory research has been conducted to illustrate meaningful end-use applications for water hyacinth-based products. Economic evaluation now needs to be made of these end-use potentials for U.S. conditions.

FOREWORD

This report was prepared under NASA Contract NASw-2800, with NASA Headquarters, Office of Applications. The work was performed by a multidisciplinary study team at Battelle's Columbus Laboratories, headed by Dr. A. C. Robinson. Team members were J. L. Otis (principal investigator) and Dr. M. E. D. Hillman (biomass utilization and technical review). Several other individuals made important contributions including W. M. Jamieson (economics), Dr. J. H. Litchfield (proteins and vitamins) and T. J. Collier (pulp).

The work reported herein was in support on an ongoing NASA program on the utilization of water hyacinths. This program is managed by Mr. Nelson L. Milder, Code ET, NASA Office of Applications.

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REVIEW OF R&D ON WATER HYACINTH
UTILIZATION IN THE PHILIPPINE REPUBLIC

by

J. L. Otis and M. E. D. Hillman

INTRODUCTION

In January 1976, Battelle's Columbus Laboratories (BCL) issued a final report entitled "An Analysis of the Market Potential of Water Hyacinth-Based Systems for Municipal Wastewater Treatment" to the NASA Office of Applications under Contract Number NASw-2800. One of the conclusions given in the report was that "There is no usage of the harvested hyacinths which can now be said to alter the cost comparison (between hyacinth-based and conventional systems) significantly. The market value of the potential products is too low to offer much hope for offsetting any substantial fraction of the cost of water treatment."

After Battelle's report was issued, Mr. Godofredo G. Monsod, Jr., President of the Hyacinth Research and Development Corporation of Quezon City, R.P., brought to NASA's attention several of his activities relating to uses of harvested water hyacinths. Based on a preliminary investigation by the Department of State it was determined that Mr. Monsod evidently is held in high esteem by both the governmental and scientific communities in the Philippines and has been performing R&D with the objective of inventing processes and products relating to the conversion of harvested water hyacinths into useful products. Because economical conversion of hyacinths into products would improve the prospects for use of hyacinths in water treatment, NASA was interested in an assessment of the impact of Mr. Monsod's developments on water treatment potential. Accordingly, Battelle was authorized to undertake the study described herein.

In brief, Battelle activities included: (1) a limited literature study, (2) personal, in-depth interviews with Mr. Monsod and his associates in the Philippines, (3) preliminary analysis and evaluation, (4) discussions with selected BCL specialists, and (5) preparation of ~~this~~ report.

OBJECTIVES

The objectives of the Philippine water hyacinth utilization study were twofold:

- (1) To obtain from Mr. Monsod and his associates as much information as possible relating to the technical and economic merits of his developments for conversion of water hyacinths to useful products
- (2) To evaluate the potential impact of these developments on the market potential for water hyacinth-based systems for municipal wastewater treatment in the United States.

SCOPE

The scope of the information acquired about Mr. Monsod's developments was as broad and deep as possible, limited primarily by Mr. Monsod's willingness to make disclosures. Battelle sought information about all his endeavors relating to water hyacinths, including the following:

- Proposed harvesting techniques, volumes, and costs
- The "Monsod Mechanical Process" for defibering
- Animal feeds
- Paper fibers
- Particle, acoustic, and insulation boards
- Food, pesticide, medicinal, and pharmaceutical products
- Vitamin A
- Other minerals and vitamins.

The evaluation of the potential impact of such developments presented herein is necessarily preliminary and judgmental in nature because of the limited study scope.

PROCEDURAL APPROACH

The approach taken in this evaluation of the conversion of water hyacinths to useful products in the Philippines was to:

- (1) Establish a background for the investigation by means of a general knowledge of the current state of hyacinth R&D

(2) Investigate the technological basis for and capability of the Monsod operations

(3) Analyze and evaluate the information obtained.

The procedures used in the investigation included (1) a limited literature study; (2) personal, in-depth interviews in the Philippines with Mr. Monsod and his associates; (3) preliminary analysis and evaluation; (4) discussions of the analysis and evaluation with selected Battelle specialists; and (5) concluding analysis and evaluation.

Interviews with Mr. Monsod and his associates were conducted during three workdays. Mr. Monsod made tape recordings of those interviews conducted in his office. No written secrecy agreement was entered by the principals involved in the interviews. The manner in which Mr. Monsod presented information to the principal investigator was as follows:

- Unilateral lecture on the first day
- Bilateral discussion and answering questions on the second and third days
- Viewing of a movie and slides
- Presentation for observation and/or analyses of selected samples
- Viewing of displays in his office of various materials including flowsheets, maps, documents, analytical data, samples, photographs
- Provision of copies of selected written materials
- Introduction of and discussions with two of his associates--Dr. Solon and Dr. Santos.

Although the principal investigator offered to accompany Mr. Monsod during tours of areas where hyacinths are grown and laboratories where work was either under way or had been conducted, no such tours were arranged. Thus, Battelle was unable to actually observe processes and the resulting products from known operations.

In view of the limited physical evidence of physical processing equipment and limited demonstration of actual processes, Battelle's evaluation depends to an appreciable extent on judgments of Mr. Monsod's capability. Accordingly, the history of his related activities, and the testimony of others who are acquainted with his work, are of some significance.

In brief, Mr. Monsod's primary current interests are those of an inventor/entrepreneur/promoter. He employs a staff of 23 people, including 4 consultants, for his three companies, one of which is Hyacinth Research and Development Corporation. Biographical data, provided by Mr. Monsod during the visit, are included in Appendix A.

EVALUATION RESULTS

Monsod states that his work has been based on the "cottage industry" concept, wherein families would harvest the plants from hyacinth lagoons and prepare intermediate products suitable for mechanical defibering. Application of the cottage industry concept is common in the Philippines, and in Southeast Asia generally. This orientation is normal for the Philippine environment and probably for certain other developing countries. Certain aspects of his proposed system would not be applicable in the United States and similar nations; these will be noted later in the sections discussing specific processes.

Battelle believes that the single most important research finding of Mr. Monsod's efforts to date relates to the concept that useful products could be prepared from water hyacinths if the highly fibrous portion of the plant were separated from the other components. Use of such water hyacinth "fiber" as feedstock for pulp production would probably eliminate several of the problems identified by the University of Florida when the whole plant was used as feedstock in its experiments. Furthermore, use of the "defibered" portion of the plant as an animal feed protein supplement would eliminate concern about digestibility of the hyacinth plant materials because of high cellulose content.

Monsod Hyacinth Utilization Concept

A simplified block diagram type of flow sheet of Mr. Monsod's conceptual utilization system is presented as Figure 1, based on BCL's understanding. The more important unit operations and utilization concepts, apparent status of R&D, and relative importance are discussed in the sections that follow.

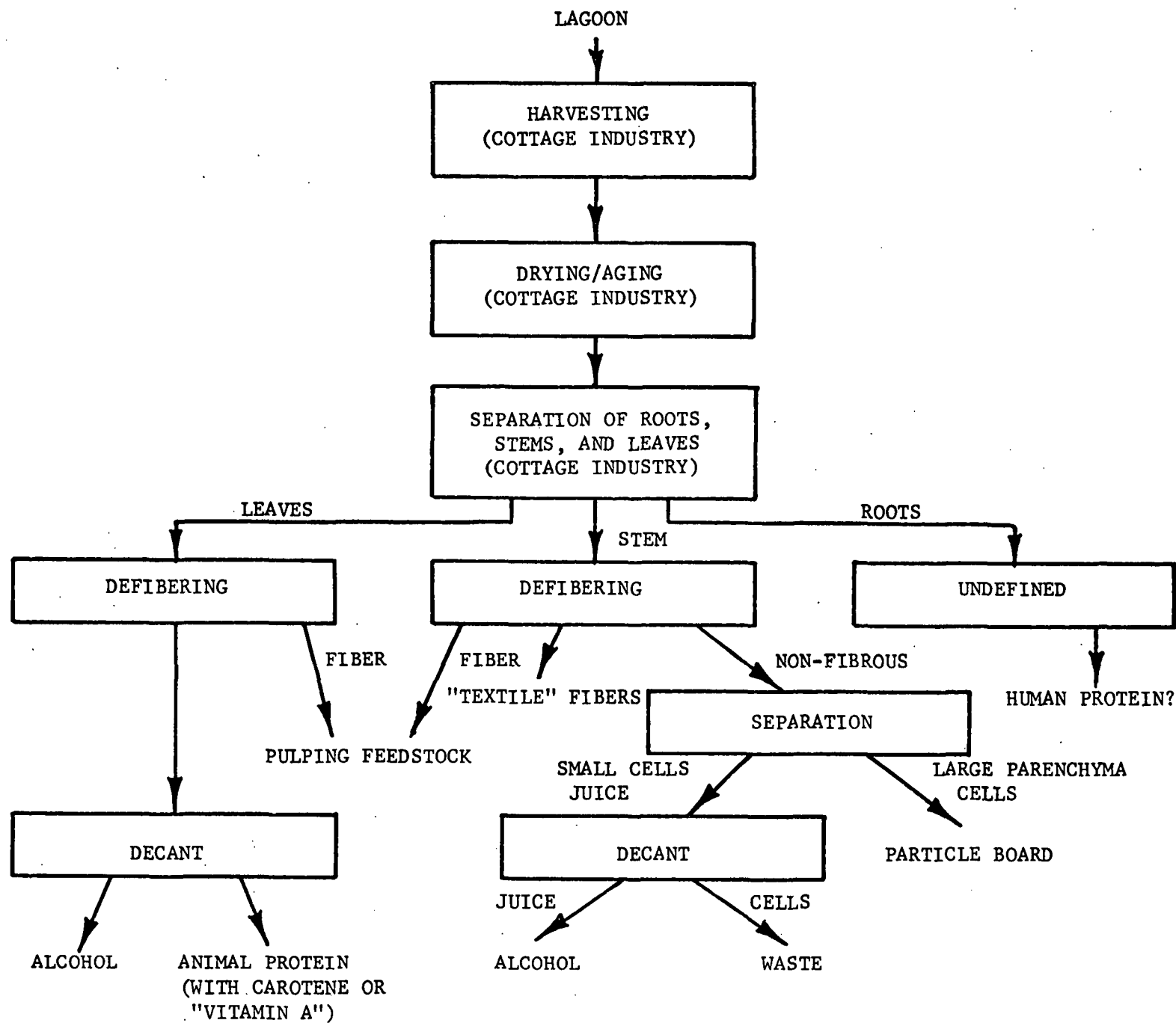


FIGURE 1. SIMPLIFIED FLOWSHEET OF MONSOD'S HYACINTH UTILIZATION CONCEPT

Harvesting

Hyacinth plants would be harvested either from lagoons used for pollution control, or from lagoons used specifically to produce the plants for utilization. If human food or animal foods are being considered as products, the plants should be free of heavy metals. As conceived by Monsod, the harvesting step would be relatively labor intensive. However, he has considered the utilization of mechanical equipment. In addition, he is considering applying for a patent on a mechanical suction device, analogous to a vacuum sweeper, for harvesting. Although the principal investigator was shown a diagram of a nature and quality similar to diagrams used to obtain U.S. patents, Mr. Monsod did not care to discuss operational features. It is believed that such a device has not yet been reduced to practice by Mr. Monsod. Furthermore, the validity of the concept for use with water hyacinths is doubtful because of the growth habit of the plant. The significance of this development is believed to be negligible for application in the Philippines or elsewhere.

Drying and Aging

Although the drying and aging steps are shown in Figure 1 immediately following harvesting, they may actually occur after separation of the leaves, stems, and roots and other steps such as separation of parenchyma cells from the non-fibrous residue (after the defibering step). Aging and solar drying would be performed as a part of the cottage industry activity. Monsod presented no research or development results about these steps.

Separation of Leaves, Stems, and Roots

Based on the Monsod approach, the cottage industry would be employed to cut by hand the leaves and roots from the stems. No mechanical device has been proposed. Although the question had occurred to us during the interviews, we did not ask if it was really necessary to physically

separate these parts of the plant to achieve appropriate defibering in subsequent operations. If not, the necessity of substantial hand labor or development of a suitable complex mechanical device could be avoided.

Defibering of Leaves and Stems

After Mr. Monsod first conceived of the possibility of successful applications by defibering the leaves and stems of the plants, early trials were made with an abaca fiber (derived from banana plant leaves) machine. Although high quality fiber was produced, from stems, by the abaca machine (similar in appearance to the artificial coarse blond hair used for toy dolls), the fiber yield was very low--on the order of 10 to 15 percent. Mr. Monsod continued defibering efforts by modifying a corn-milling machine and applying special processing techniques. Based on limited knowledge related to the processing of other plant materials, the elements of the methodology seem to make technical sense. According to Monsod, he is now openly claiming fiber recoveries of 50 to 70 percent; he privately claimed 80 percent recovery, but with the inclusion of large quantities of parenchyma cells.* A movie of the modified corn-milling machine in operation using leaves as feedstock was shown to the principal investigator. This movie was not exceptionally convincing, particularly with respect to the true nature of the products produced during the run. Furthermore, Mr. Monsod did not care to delineate details of the mechanical modifications required. However, when the principal investigator indicated the desirability of personally seeing the device in operation, Mr. Monsod expressed the belief that the movie was enough.

This type of technological development, if verified for hyacinths, would be of major significance in further water hyacinth utilization development. A BCL specialist surmised that Mr. Monsod may have utilized known technology employed for other plant materials in other countries (e.g., India).

* The parenchyma cells do contain short fibers but are very dark in color when pulped and converted into hand sheets. The inclusion of minor parenchyma probably would not be exceedingly detrimental.

Possible Commercial Uses for Hyacinth Products

A chart displayed in Mr. Monsod's office gave an indication of some of the properties of hyacinth raw products. Although incomplete, the data are presented here as Table 1; it should be noted that any clarification we were able to obtain from Mr. Monsod has been added to the table in the form of footnotes.

Use of Roots For Human Protein

At present, immature roots and rizomes of the water hyacinths are being consumed by some humans as vegetables and as an ingredient of salads, according to Mr. Monsod. There is a major palatability problem in preparation of an acceptable human protein supplement from roots. Apparently, a very sharp bitter aftertaste continues for about 30 seconds after consumption. A process would be required to remove the cause of this effect for a successful end-use application. If this problem were solved, then utilization of the roots for human protein supplement might be conceived of as fitting very well into the programs sponsored by the "Nutrition Center of the Philippines" and similar programs in other countries.

Stem Fiber for "Textile" Applications

Samples of natural and dyed coarse fibers from the stem were on exhibit. Although the word "textile" is and was employed, the only end-use application shown was samples of household place mats. No suggestions were made for fiber use in the manufacture of more conventional fabrics. Although this application may be suitable for developing countries, it would probably not be appropriate for the United States.

Fibers for Paper-Making Pulp

Samples of leaf and stem fibers produced by the defibering operation have been soda pulped. Handsheets of paper have been produced from these

TABLE 1. ANALYSIS OF VARIOUS PRODUCTS OUT OF WATER HYACINTH
PLANT, PHILIPPINE TEXTILE RESEARCH INSTITUTE,
PHILIPPINE SUGAR INSTITUTE AND ATENEO UNIVERSITY
CHEMISTRY LABORATORY DIVISION^(a)

Product	Tensile Strength KGS (GM) Meter ^(b)	Average Cellulose Content, percent	Glucose Content ^(c) percent	Alcohol Content ^(d)	
				Type	Composition
Stems - cellulose fiber	13.9	84.84	--	--	--
Leaves	--	70.46 ^(e)	--	--	--
Stem juice	--	--	8.12	Ethanol Methanol	38% (vol.) 8 ppm
Leaf juice	--	--	7.90	Ethanol Methanol	63% (vol.) 3 ppm

(a) All footnotes have been added by Battelle.

(b) This unusual unit has not been clarified by Battelle. It is a textile unit.

(c) Glucose content measured after evaporation and probably before fermentation.

(d) Alcohol content after fermentation and distillation.

(e) Probably based on leaf fiber product.

fibers both before and after bleaching. In addition, handsheets have been produced from pulped parenchyma cells.

The results of these paper-making experiments have been much more encouraging than trials conducted by the University of Florida (U.F.) which were based on utilization of the whole plant in chopped form. However, certain problems identified by U.F. probably remain, but not to the same extent; these include the following:

- Low freeness (drainage rate)
- Low overall yield based on whole plant dry matter weight
- Low quantity of cellulose that can be charged to digester (low bulk density)
- High cooking liquor requirement in terms of volume per unit mass of fiber charged.

Nevertheless, the paper product produced from the fibers proved to be very interesting and quite different from that from the U.F. trials in important respects (see Appendix B). It had :

- High tensile, tear, and burst strengths
- Good stiffness
- Good wet strength
- Low brightness (but not unacceptably dark for all uses)
- Low inherent opacity
- An odor similar to that of styrene--butadiene latex was noted when one paper sample was heated. (This odor might be attributable to either residual material from prior non-hyacinth trials, or decomposition of a natural organic material in the hyacinth pulp.)

Analysis of the paper sample produced from pulped parenchyma cells tends to indicate the reasons for the differences in results:

- Short fiber length
- More of a "brittle" property (stiff without tensile or tear strengths).
- Dark brown color
- Extremely low freeness probable
- Blistering upon heating
- Probable major bleaching problem.

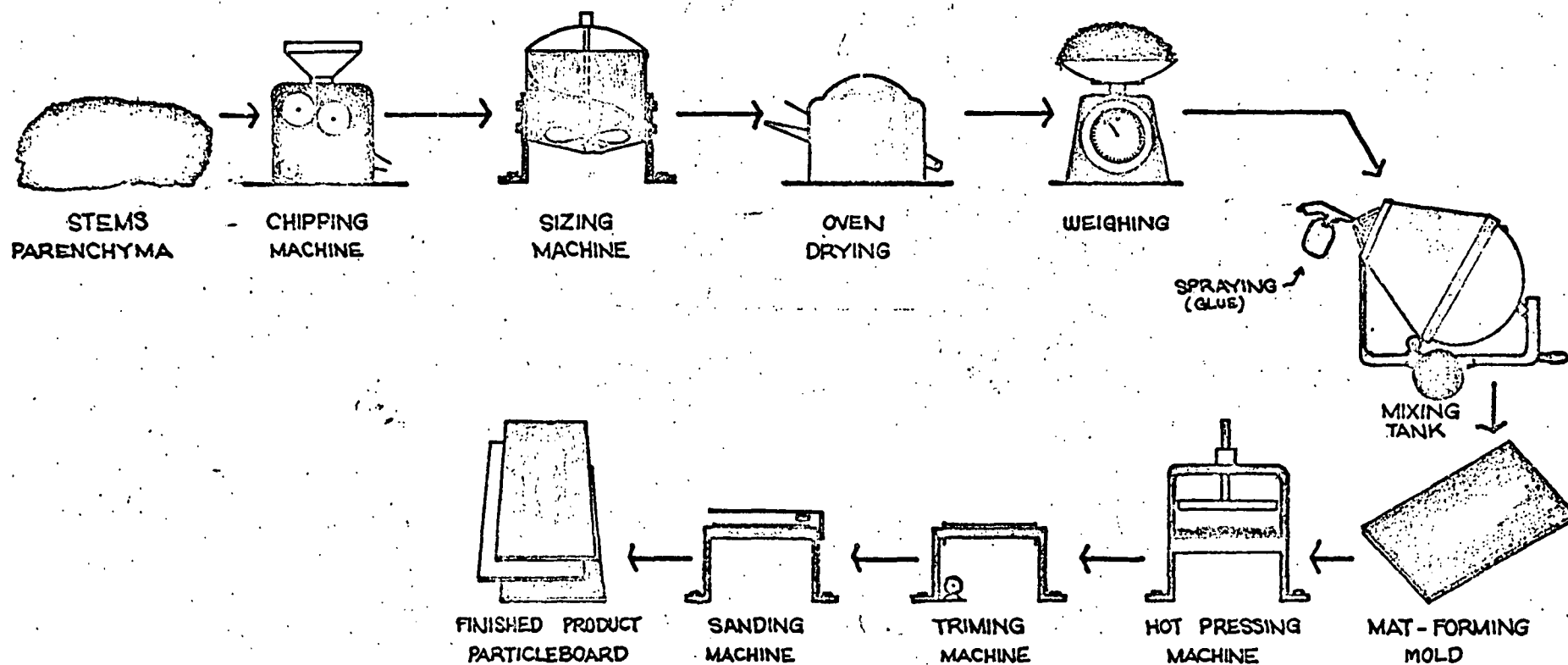
Opportunities for commercial use can only be tentatively suggested at this time, subject to further evaluation. These include addition to kraft softwood pulp to produce a food packaging board, specialty papeteries*, and other specialty applications such as filters. Mr. Monsod suggests their use for currency and teabags; the currency use probably has merit.

Battelle concludes that laboratory work has been performed which demonstrates the potential technical feasibility of hyacinth pulp utilization in commercially significant applications in the United States and other countries. More detailed information about research findings is presented in Appendix C.

Parenchyma (and Fibers) for Particle Board

Mr. Monsod has proposed the use of parenchyma cells and/or fibers for particle, acoustic, and insulation boards. The Monsod process for the manufacture of particle board from hyacinth parenchyma is illustrated in Figure 2. Experimental panels have been made that illustrate the potential feasibility. In fact, other materials including wood chips and scrap rubber have been incorporated in the illustrative boards in various configurations such as wood chip cores with hyacinth parenchyma and fiber facings. Although the quality of the boards displayed was poor, this does not negate the apparent technical feasibility. The boards displayed are estimated by BCL to be relatively dense, approximately 45 to 50 pounds per cubic foot, probably due to high concentrations of polymeric binder. (This estimate of density was based only on holding a small sample board.)

* A wide variety of writing papers which may be all sulphite of varying percentages of rag content with numerous finishes in basis weights from 17" x 22" - 13 pounds to 32 pounds. This grade is normally used for personal correspondence, and so must be sized for pen and ink, have good opacity and fold well. Reference: Packet Encyclopedia of Paper and Graphic Arts Terms, Thomas Printing and Publishing Company., Ltd., 2nd Edition.



GODOFREDO G. MONSOD, JR.

INVENTOR

PATENT APPLIED FOR

research
HYACINTH & CORP.
 development

FLOW SHEET FOR THE MANUFACTURE OF PARTICLEBOARD

FIGURE 2. MONSOD FLOWSHEET FOR MANUFACTURE OF PARTICLE BOARD FROM HYACINTH PARENCHYMA

Although hyacinth-based particle boards cannot yet be claimed to have been developed sufficiently to compete in U.S. markets, it is believed that eventual proof of technical/economic feasibility is a reasonable possibility after commitment to an appropriate research and development program. The markets are large, and thus there is the possibility of a significant utilization potential. Economic evaluation of this potential should be performed prior to major commitment to technical R&D. Product quality requirements for this type of product in developing countries are probably not as severe as in U.S. markets.

Alcohol (Ethanol) Production

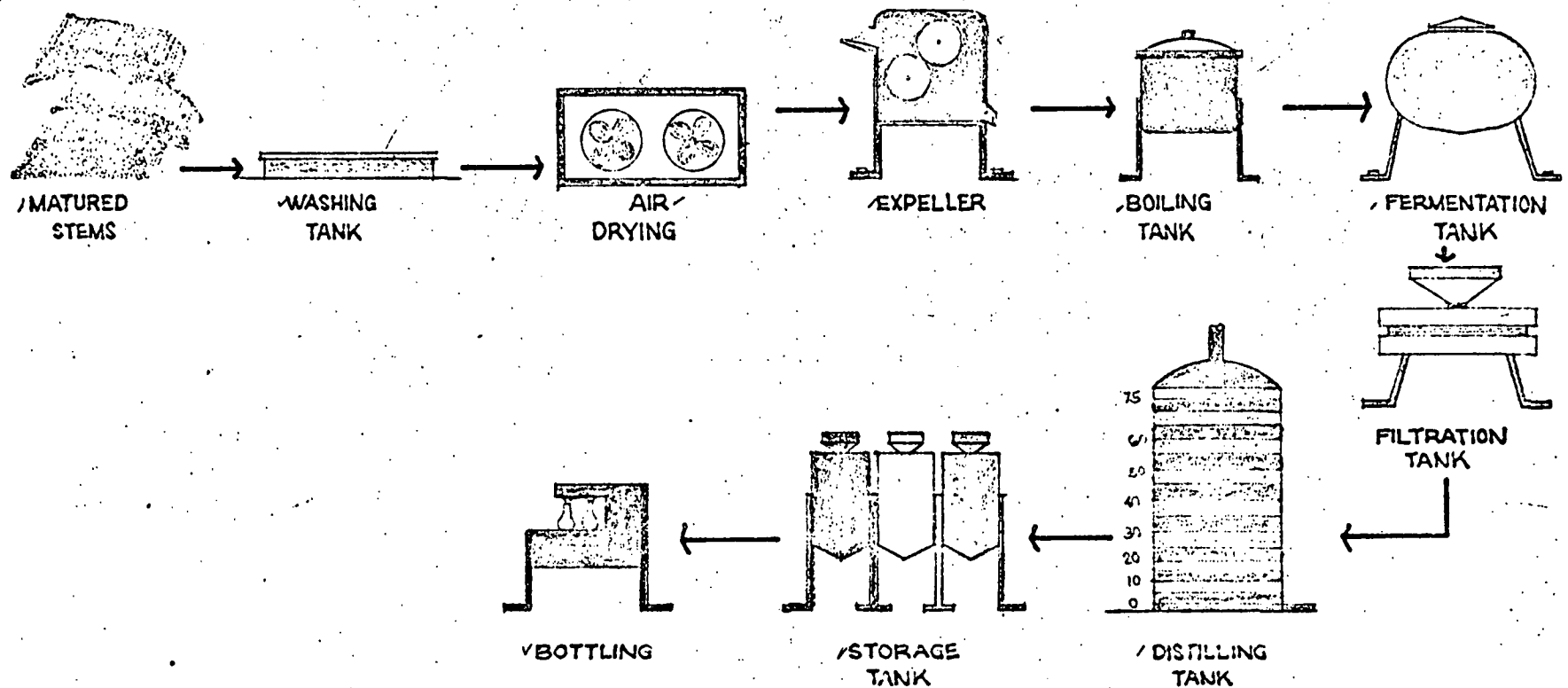
The raw juice from the leaf defibering operation is a liquid containing numerous (green) plant cells which, upon standing, settle to produce a clear juice and a cell concentrate referred to as a "leaf protein concentrate". In Monsod's utilization scheme, the clarified juice from decantation would be evaporated for the concentration of sugar (glucose) and then fermented to produce ethanol. Figure 3 illustrates Monsod's envisioned ethanol production process. Although actual fermentation of hyacinth juice to produce ethanol may be novel, Monsod conceded that there were no particularly unique process steps. This subject was not explored further; it is doubtful that ethanol produced in this manner could compete effectively with alternative ethanol processes and/or raw materials.

Juices from both the stem and leaves were concentrated by evaporation to about 8 percent "glucose", then fermented by conventional processes. Finally, the fermentation product was distilled to produce ethanol at about 50 to 65 volume percent containing about 3 to 8 ppm methanol.

Animal Protein Production

Mr. Monsod has been very active in promoting the construction of an animal protein production facility, without success. Proposed plant investment (early 1976) would be 15 million pesos (U.S. \$2.06 million) and

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GODOFREDO G. MONSOD, JR.

'HYACINTH' research & CORP.
development

FLOW SHEET FOR ALCOHOL and WINE PRODUCTION

PATENT APPLIED FOR

FIGURE 3. MONSOD FLOWSHEET FOR PRODUCTION OF ETHANOL FROM HYACINTH JUICE

the Philippine government is considering providing capital of 2 million pesos (U.S. \$0.275 million). Major aspects to be discussed regarding protein include analyses, differences in leaf- and stem-derived protein concentrate, chicken feeding trials, and carotene (Vitamin A).

Analytical Data. Mr. Monsod had various displays of analytical data for proteins in his office. These data are presented in Tables 2 through 6. cursory review of the data by a BCL animal feed specialist indicated that they appeared reasonable and that the protein concentrates would be of some nutritional value if used as feed supplements. Table 2 presents data for various parts of the plant, intermediate products, and protein concentrates. Table 3 repeats some of the data of Table 2 and adds comparable data for casava leaves and tubers, fish meal, and chicken manure. Table 4 presents an analysis of the essential amino acids in leaf protein concentrate, along with such data for corn endosperm, soya bean meal, meats, eggs, and milk. Analytical data of mash to be used for various types of chicken feeds are given in Table 5. Although details about quantities of specific ingredients were not discussed, mixtures of other materials, including casava leaves, were incorporated into the suggested feeds. Table 6 provides analytical data on various suggested rabbit and chicken feeds based on processed recycled chicken manure and leaf protein concentrate. (Monsod objects to the current practice of recycling unprocessed chicken manure.) Figure 4 illustrates the Monsod process for recycling manure from hyacinth-fed poultry.

Leaf Protein, Vitamin A, and Chicken Feeding Trials. On the basis of the analytical data, Mr. Monsod placed great emphasis on the possible use of leaf cells after fiber removal as an animal feed protein source. Analysis for carotene by an unspecified method revealed about 53,000 International Units expressed as Vitamin A per 100 grams of concentrate. However, other plant materials are readily available as Vitamin A sources. Thus, the importance of the Vitamin A analysis has probably been overemphasized by Mr. Monsod--particularly for conditions in the United States.

Mr. Monsod has seriously pursued development of feeds for chickens and rabbits based on the premise that many Filipino households should grow

TABLE 2. ANALYSIS OF VARIOUS PRODUCTS OUT OF WATER HYACINTH PLANT,
FOOD AND NUTRITION RESEARCH INSTITUTE AND BUREAU OF
ANIMAL INDUSTRY, LABORATORY DIVISION

Product	Protein	Fat	Fiber	Moisture	Ash	NFE	Calcium	Phosphorus	Vitamins: (in Mg)			
									A	B ₁	B ₂	Niacin
Roots	11.8	0.5	7.9	11.2	27.0	41.6	1.03	0.67				
Stems	7.4	2.2	21.4	13.3	13.2	42.5	1.62	0.55				
Leaves	18.7	3.2	17.1	11.3	13.6	36.1	2.07	0.54				
Dehydrated Stolon	6.9											
Leaf Protein Concentrate	23.2	5.0	4.3	8.6	21.5	40.0	1.86	0.61	52,735 ^(a) IU	0.32 ^(b) Mg	1.14 ^(b) Mg	4.7 ^(b) Mg
Leaf Fresh Juice (Direct Heating)	1.8			94.4								
Leaf Fresh Juice (Indirect Heating)	6.14			78.0								
Defibered Stems	8.2	1.2	20.5	17.0	22.1	31.0						

Note by BCL: Sequence of specific components changed from Monsod sequence.

(a) Actually carotene analysis by unspecified method per 100 grams leaf protein concentrate.

(b) Mg per 100 grams leaf protein concentrate.

TABLE 3. ANALYSIS OF FEED COMPOSITION (PERCENT)
BUREAU OF ANIMAL INDUSTRY
ANIMAL NUTRITION LABORATORY

Ingredient	Protein	Fat	Fiber	Moisture	Ash	NFE	Calcium	Phosphorus
Water lily leaves	18.7	3.2	17.1	11.3	13.6	36.6	2.07	0.54
Lily leaf protein concentrate	23.2	5.0	4.3	8.6	21.5	40.0	1.86	0.61
Water lily roots	11.8	0.5	7.9	11.2	27.0	41.6	1.03	0.67
Dehydrated stolon	6.9	1.0	12.5	8.6	67.0	67.5	-	-
Casava leaves	28.05	3.85	12.58	6.58	5.50	-	0.50	0.19
Casava tubers	1.9	0.67	0.85	12.10	1.44	5.04	0.15	-
Fish meal	57.86	10.64	1.75	8.64	14.87	-	3.03	0.29
Chicken manure	17.8	0.4	11.2	11.4	28.6	30.2	3.83	1.21

TABLE 4. THE ESSENTIAL AMINO ACID COMPOSITION OF LEAF
PROTEIN AND OTHER GOOD QUALITY PROTEIN SOURCES*

Protein Sources	Amino Acids (g/100g Protein)						Tryptophan
	Lysine	Methionine	Threonine	Isoleucine	Leucine	Valine	
Leaf Protein	6.3	6.0	5.2	9.8	5.3	6.3	1.6
Corn endosperm	3.6	4.5	5.7	10.5	3.8	5.7	-
Soya bean meal	6.4	4.8	3.7	3.5	6.2	5.0	1.2
Meat, poultry, fish	8.1	4.9	4.6	7.7	6.3	5.8	1.3
Eggs	7.2	6.3	4.3	8.0	4.2	7.3	1.5
Milk	8.2	5.7	4.5	8.5	11.3	8.5	1.6

* FAO, Rome (1970) Amino Acid Composition of Foods

Leaf protein contained more lysine than the best high lysine corn and more methionine than soya bean meal. The non-essential amino acids also occurred in a favorable balance and there was sufficient of each to provide a well balanced dietary protein.

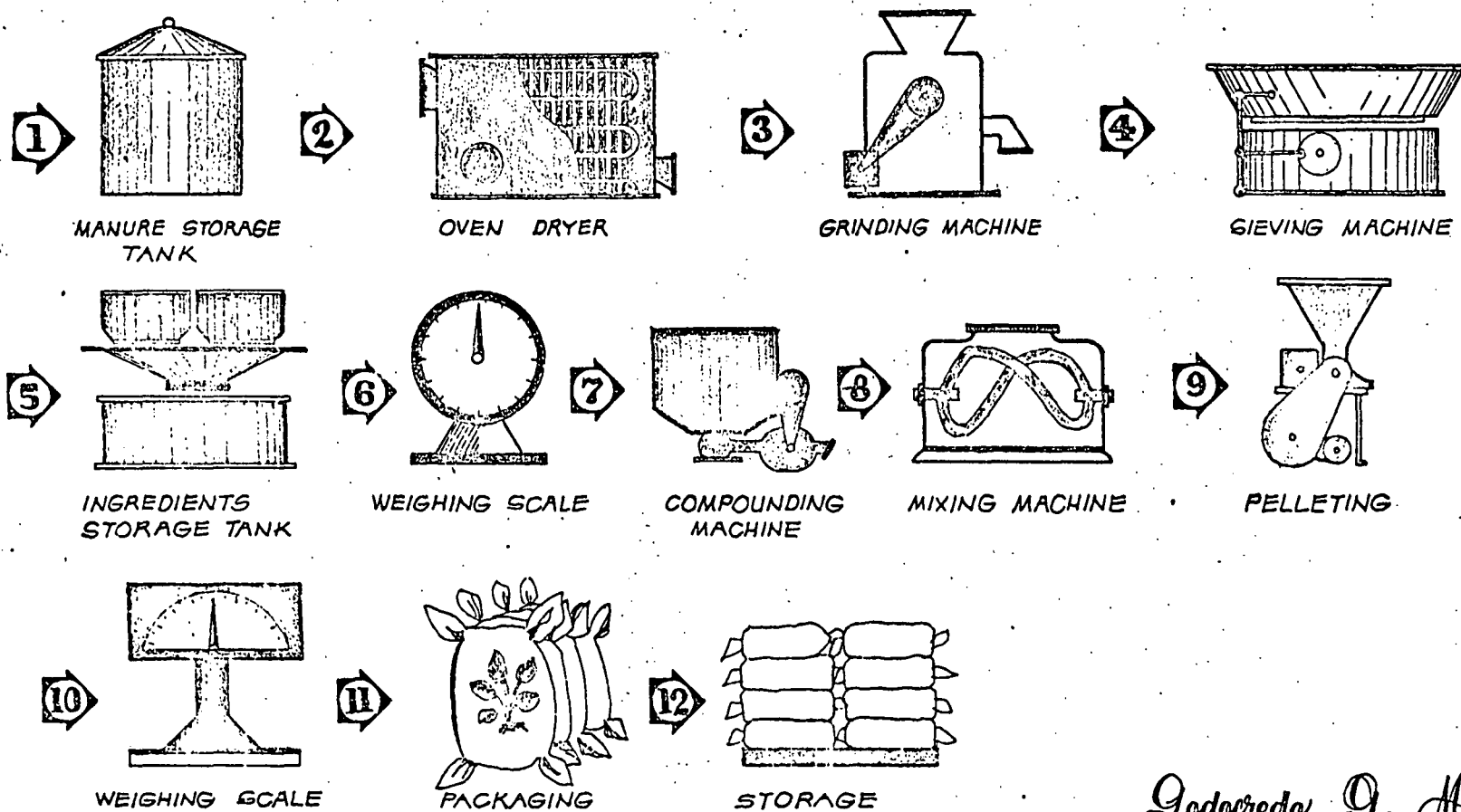
TABLE 5. ANALYSIS OF FEED COMPOSITION, ANALYZED BY THE BUREAU OF ANIMAL INDUSTRY,
ANIMAL NUTRITION LABORATORY, REPUBLIC OF THE PHILIPPINES

	Protein	Fat	Fiber	Moisture	Ash	NFE	Calcium	Phosphorus
Broiler mash	21.1	2.0	4.7	8.1	15.2	48.9	1.69	0.85
Starter mash	19.1	2.3	5.2	8.6	15.3	48.5	1.87	0.79
Grower mash	16.9	2.0	5.8	8.4	16.9	50.0	1.77	0.65
Layer mash	15.8	2.3	5.7	8.3	15.5	51.4	2.31	0.60

TABLE 6. ANALYSIS OF FEED COMPOSITION (RECYCLED CHICKEN MANURE) ANALYZED BY THE BUREAU
OF ANIMAL INDUSTRY, ANIMAL NUTRITION LABORATORY, REPUBLIC OF THE PHILIPPINES

	Protein	Fat	Fiber	Moisture	Ash	NFE	Calcium	Phosphorus
Rabbit and Starter Pellets	20.3	7.3	4.7	8.4	7.8	51.5	1.52	0.72
Rabbit and Grower Mash	13.8	2.5	7.6	9.4	17.6	49.0	3.80	0.88
Layer and Grower Pellets	20.0	2.5	3.7	8.2	10.5	55.1	1.38	0.70
Chicken Droppings	17.8	0.4	11.2	11.8	28.8	30.2	3.83	1.21

FLOW SHEET DIAGRAM FOR RECYCLING POULTRY MANURE INTO HYGIENIC
PROTEIN-RICH FERTILIZER FOR FRESH-WATER SHRIMP OR FISH PONDS OR
PLANKTON LIFE CONDITIONER



Godofredo D. Monsod Jr.
INVENTOR

PATENT APPLIED FOR

FIGURE 4. MONSOD FLOWSHEET FOR RECYCLING MANURE FROM HYACINTH-FED POULTRY

their own meat supply in backyard coops. Thus, a chicken feeding trial was conducted. One of his findings from the trial was that the chicken manure from hyacinth product-fed flocks had virtually no foul odor, which he attributed to the presence of a high concentration of chlorophyll. However, Battelle doubts the technical validity of this trial because the typical odor attributable to chicken manure is ammoniacal, upon which chlorophyll would be expected to have little impact. Battelle believes that properly cleaned chicken coops would not be expected to produce substantial foul odor; a controlled feeding trial would be an appropriate study technique in this case.

Stem Protein. Mr. Monsod had a sample of stem protein "gel". Apparently, if a moist stem "protein concentrate" is heated for evaporation to a dry condition, a gelatinous type of product forms prior to substantial water removal. Because of this, Monsod is not promoting the development of the equivalent of a stem protein concentrate as a realistic utilization scheme.

BCL Conclusions Regarding Protein Concentrate. Based on the analytical data obtained, Battelle concludes that utilization of hyacinth leaf materials for protein supplement might possibly prove to be of significant impact in the United States. However, Monsod's work has been directed primarily to chicken feeds, and not cattle feeds. Although significant numbers of chickens are grown in the Southeastern United States, the markets are not necessarily near hyacinth growth areas. Careful technical-economic assessment beyond the scope of this study would be required to make an accurate evaluation of technical-economic feasibility.

Insecticide/Pesticide

Mr. Monsod refused to discuss any important details about production of an insecticide from hyacinth materials prior to obtaining patent protection. He did make a declaration that the insecticidal properties are provided by the hyacinth stem materials and not the added chemicals. Incidentally, the product would be sold as a "pesticide" to agricultural markets and as an "insecticide" to household markets--an interesting distinction.

Potential Applications

No effort was made to discuss utilization of hyacinth materials for soil conditioners or fuel gas. Soil conditioner use would be of a disposal type, and Battelle has previously evaluated the fuel gas potential. Although Monsod's publications/exhibits showed application as deodorant (chlorophyll based?) and for medicines/minerals, these were not claimed by Monsod during interviews.

CONCLUSIONS AND RECOMMENDATIONS

Mr. Monsod's R&D effort is oriented toward a "cottage industry" commercialization wherein entire families would become involved and contribute significant low-cost labor to harvest and produce intermediate products. As a consequence, his utilization system as now conceived would be less appropriate for use in the more industrialized nations such as the United States. However, it appears that important exploratory research has been conducted to illustrate meaningful end-use applications for water hyacinth-based products. In addition, it appears that Mr. Monsod has demonstrated the feasibility of separation of the leaf and stem fibers from other portions of the water hyacinth plant.

The task of evaluating the principal interview findings involves some difficulty because Battelle must exercise a significant amount of trust in accepting the comments of Mr. Monsod and the data he provided. We believe that such acceptance is generally justified, based upon review by Battelle specialists of the limited data provided. However, Battelle recommends that some of Mr. Monsod's results be reconfirmed prior to major R&D commitments based on his findings. (His assistance would probably be required for any defibering endeavors.)

Status of Development Areas and Degree of Technical Feasibility and Importance

The principal areas of Mr. Monsod's efforts are presented in Table 7, along with the status of development and BCL's judgment as to technical

TABLE 7. DEVELOPMENT AREAS, STATUS, DEGREE OF TECHNICAL FEASIBILITY, AND IMPORTANCE OF MR. MONSOD'S R&D EFFORTS

Development	Status	Tentative BCL Judgment of Technical Feasibility of Monsod's Development ^(a)	Preliminary BCL Assessment of U.S. Importance
Harvesting	Machine concept	Doubtful	Negligible
Defibering	Machine/method demonstration	Probable	Very significant
Protein-animal	Laboratory (pilot) workup	Probable	Significant
Protein-human	Conceptual	Possible, with difficulty	Nil
Vitamin A (carotene)	Analyses	Possible	Negligible
Alcohol (ethanol)	Laboratory workup	Probable	Negligible
Pulp (paper)	Laboratory demonstration	Probable	Possibly significant
Textile fibers	Laboratory illustration	Improbable	Negligible
Particle boards	Laboratory illustration	Probable	Possibly significant
Pesticide/insecticide	Unknown ^(b)	No judgment ^(c)	Unknown
Soil conditioner	Not discussed	Probable	--
Fuel gas	Not discussed	Probable	--
Deodorant	Not claimed ^(d)	No judgment ^(c)	--
Medicines/minerals	Not claimed ^(d)	No judgment ^(c)	--

(a) Because of the nature of the evidence presented to the principal investigator, all judgments are tentative and should be verified in laboratory work.

(b) Monsod refused to make significant disclosures during interviews relative to one product (called a pesticide if for agricultural use or insecticide if for home use) except to say the insecticidal properties were derived from the hyacinth and not by the chemicals added for processing.

(c) No judgment is possible because of lack of information provided by Mr. Monsod.

(d) Monsod made no claims during interviews for the types of products indicated.

feasibility and the possible importance of the development for conditions in the United States.

Mr. Monsod's major potential contributions that would support the NASA-OA hyacinth development probably relate primarily to: (1) the de-fiberizing operation and subsequent utilization of the fibers for paper pulp and (2) use of other plant materials for animal feed supplement and particle boards. Economic evaluation of these end-use potentials for U.S. conditions needs to be made.

Overall Assessment of Impact on Market Potential

It was beyond the scope of this brief study to perform sufficient technical-economic evaluation to enable BCL to assign values for the probabilities of successful commercialization of the various elements of the Monsod system. However, the possibilities of success seem reasonably good and are believed sufficient to justify further techno-economic analyses. If the major elements of the Monsod system were combined into a successful commercialization, the chances of achieving greater market penetration than that estimated in the January 1976 Battelle report appear to be good. This statement assumes that either a mechanical device is developed to separate leaves and roots from stems or that such physical separation is not required.

APPENDIX A

MONSOD CAREER, STAFF, AND FACILITIES

(Biographical data and staff
listing supplied by Mr. Monsod)

APPENDIX A

MONSOD CAREER, STAFF, AND FACILITIES

Basically, Mr. Monsod's career can be traced from the age of 17 to 21 (1942-1946) as an army officer, from the age of 33 to 47 (1957 to 1972) primarily in the government service (legislative staff), and from the age of 48 to 51 (1973 to 1976) as an "inventor". (His activities from 1946 through 1956 and from 1965 through 1968 were not discussed.) His biographical sketch is presented at the end of this Appendix.

A visit at the Nutrition Center of the Philippines was arranged by Mr. Monsod. Mrs. Imelda Romualdez Marcos, the Philippines' First Lady, is Chairman and President of the Center. During the visit, Dr. Florentino S. Solon, Executive Director, and Dr. Ibarra Santos Santos were interviewed. The comments of Dr. Solon were primarily related to the worthy activities of the Center. It was made clear that the Center was somewhat interested in the possibility of deriving human food from water hyacinth. In fact, Mrs. Marcos' conference room in the Center had a display board of approximately 2 by 3 feet about the potential of protein recovery from water hyacinths by the Monsod concept. However, no significant or proactive program in this area is being conducted by the Center.

Discussion with Dr. Ibarra Santos Santos (plant breeder and geneticist, Supervising Scientist and Head, Department of Agricultural Sciences, Philippine Atomic Research Center, Philippine Atomic Energy Commission) was much more convincing toward establishing credibility of Mr. Monsod's program than any other single factor. Dr. Santos serves as a highly respected consultant to both Mr. Monsod and the Nutrition Center, is obviously intelligent and well read, and has visited with counterpart Battelle specialists in Columbus.

Monsod Organization

During interviews, the existence of a very large staff became apparent. Accordingly, a listing of personnel including consultants was obtained, and is presented later in this Appendix. At the present time, this staff works for

Mr. Monsod not only on the water hyacinth program but also in other ongoing businesses at 258-C Tomas B. Morato Avenue. These include Pilipino Rubber Products, Inc., and Imbensyon Pilipino, Inc. His own staff includes 19 people plus 4 consultants according to the listing. At least four staff members were from the Monsod family.

As of September 17, 1976, Hyacinth Research and Development Corporation continued as an unincorporated organization. According to Mr. Monsod, he had not planned a formal organization until the government requested incorporation about the first of this year to allow the government to participate in financing of an animal feeds production facility. Corporate status would normally have been approved in about 6 months but because of the anticipated government participation unusual problems were encountered. These problems have recently been cleared up and the steps toward corporate status are now anticipated to proceed smoothly, according to Mr. Monsod.

Listing of Monsod Staff

Researchers

Carol Monsod
Edward Monsod
Wilma Monsod
Bartolome Espino
Teresita Felicia
Godofredo S. Monsod IV

Consultants

Dr. Ibarra Santos
Arturo Pablo
Dr. Jose Zerrudo
Lourdes Dajao

Attorney Ric Lardizabal - Legal Consultant

Ernesto Meneses
Luceno Pangan
Francisco Divina

Sixto Quiroz
Pedro Cuaresma

Magdalene Rosalin Andrada - Chemists

Leticia P. Bobis

Guia P. Yan - Bookkeeper Accountant

Lydia C. Dumotan - Secretary

Reynaldo Francisco - Artists

Agrafino Santiago

Avelino V. Subong - Writer

Monsod Facilities

The only facilities physically observed during interviews were those housed in a commercial building in a residential-commercial district. Less than a total of 1,500 square feet of area was probably involved on two floors. Although there was some space for a laboratory, this space was not significantly equipped as such. Based on viewing slides and movies, it is apparent that reasonably well-equipped facilities of others are used for most of the laboratory work performed at least in part by his own staff. Some of the facilities used are those of his consultants and nearby universities. The principal use of the facilities at 258-C Tomas B. Morato Avenue is for offices and presentation of promotional displays.

GODOFREDO G. MONSOD, JR.

Place of Birth:

Date of Birth:

Civil Status:

Married

W i f e :

Lita Sarangaya

Children:

Godofredo III

Godfrey

Godofredo IV

Emelita

Sheila Lyn

Educational Background:

High School Graduate

Nueva Ecija High School

Manager's Course

Institute for Small Scale Industry

University of the Philippines

Quezon City

Seminar Attended/Special Training:

Seminar-Workshop in Invention Development

Sponsor: Philippine Inventors Commission
1974, Quezon City

Symposium on Intra-Technology Transfer

Sponsor: Asian Productivity Organization
1975, Tokyo, Japan

Bill Drafting — Economic Research

Sponsor: Philippine Congress 1959, Manila

SEMINAR SPEAKER — POSITION PAPER ON:

Invention Development — Philippine Inventors Commission 1974

Inventiveness & Creativity — Centro Escolar University 1974

Research & Invention Development — Chamber of International Trade 1975

The Versatility of Water Hyacinth — Philippine Council on Agricultural Resources Research (PCARR) Fisheries Forum 1976

Field of Specialization:

Patenting

Invention Development and Research

Non-waste Technology

Manufacturing

Subdivision Development

Management and Marketing

(Invention Patents)

Pulp and Paper Technology

Rubber Technology

Animal Feed Formulation

C A R E E R :

Government Service, Republic of the Philippines

1. 2nd Lt., Luzon Guerilla Armed Forces, USAFIP-Northern Luzon — 1942-1946
2. *Chief Investigator*
Committee on Anti-Filipino Activities
House of Representatives — 1957-1959
3. *Technical Assistant*
Committee on Commerce-Senate 1960-1964

4. *Technical Assistant*
Committee on Agriculture and Natural
Resources—Senate — 1960-1964
5. *Technical Assistant*
Committee on Immigration, Naturaliza-
tion and Reparations
House of Representatives — 1969-1970
6. *Technical Assistant*
Committee on Ways and Means—Senate
1970-1972

Private Sector:

1. *President & General Manager*
Pilipino Rubber Products, Inc.
2. *President*
Philippine Inventors Recycling Corp.
3. *President & General Manager*
Monte Villa de Monsod Subdivision
4. *President*
Hyacinth Research & Development
Corp.
5. *President*
Imbensyon Pilipino, Inc.
6. *Director*
Philippine Invention Marketing Corp.
7. *Member*
National Cottage Industry Develop-
ment Authority
8. *Member*
Social Security System (SSS)

9. *Member*
Technical Board
Committee on Trade Assistance for
Filipino Inventors
Department of Trade
Republic of the Philippines
10. *Member*
United Inventors & Scientists of
America (USA)

C A R E E R :

HIGHLIGHTS OF ACHIEVEMENTS:

1. Participated in the liberation of 511
American Prisoners of War, Cabanatuan,
Nueva Ecija, January 30, 1945 (with the
6th U.S. Army Rangers)
2. Participated in the liberation of General
Dalton Pass, Nueva Ecija-Nueva Vizcaya
—February, 1945 (with the 25th Infantry
Division, U.S. Army)
3. Participated in the liberation of Mountain
Province leading to the surrender of Gen-
eral Yamashita—Overall Commander of
the Japanese Armed Forces in the Philip-
pines—October, 1945 (with the 6th In-
fantry Division, U.S. Army)
4. *Drafted the:*
Bill on Embroidery and Apparel Law
Bill Creating the Oil Industry Commission
Law
Bill on Trade Relations with Socialist
Countries
Bill Creating the Bureau of Standards
Law

5. *Founder:*
Philippine Electric & Ice Plant Owners
Association
Philippine Chamber of Inventors and
Technologists, Inc.

AWARDS/CITATIONS:

1. Bronze Star Medal (US) 1945
2. Purple Heart Medal (US) 1945
3. Medal and Diploma of Merit 1975
Philippine Inventors Commission
4. Awardee as Distinguished Alumnus
1974-75 Institute for Small Scale
Industries
University of the Philippines
5. Presidential Panday Pira Awards
Winner (Special Mention — 1973-74
6. Presidential Panday Pira Awards
Winner — 1974-75
7. Achievement Award
United Inventors & Scientists of
America (USA) — 1976
8. Achievement Award
Filipino Inventors Society, Inc. 1976

INVENTIONS: SEE SUMMARY BELOW

Invention No.	T I T L E	Patent Issued
1. UM-1305	Rubberized Catheter Straight Tip	10-29-73
2. UM-1306	Rubberized Catheter Spiral Tip	10-29-73
3. UM-1324	Rubberized Manhole Cover Cons- truction	11- 8-73
	Japan Patent—Pending	

4. UM-1332 Rubberized LPG Regulator 11-19-73
Japan Patent—Pending
5. 8163 Method for Lining Cars, Trucks and
Ship Bodies, Steel Tubes, Plates
and Other Metallic Bodies to Protect
Same from Abrasion, Corrosion and
Heat 3-21-74
U.S.A. Patent—Pending
Japan Patent—Pending
6. 8579 Fruit Harvesting Scaffolding and
Collector 9-26-74
7. UM-1715 Grinder for Recycling Waste or
Scrap Materials 3- 5-75
8. UM-1741 Animal Feed Composition 3-31-75
9. 9232 Method for Lining Cars, Trucks and
Ship Bodies, Steel Tubes, Plates and
Other Metallic Bodies to Protect
Same from Abrasion, Corrosion and
Heat 7-23-75
10. UM-1856 An Improved Grinder for Recycling
of Waste and Scrap Materials 9- 9-75
11. UM-1881 Animal Feed Composition 9-29-75
12. UM-1995 Slipper 12-18-75
13. 9770 Mechanical Process of Recovering
Cellulosic Fibers from the Stems of
Water Lily Plant 3-15-76
U.S.A. Patent—Pending
Japan Patent—Pending
West Germany Patent—Pending
14. UM-2160 Animal Feed Composition 4 - 21 - 76
15. Invention Animal Feed Composition
West Germany Patent—Pending
Japan Patent—Pending
U.S.A. Patent—Pending
16. 9876 Process for Extracting Valuable
Nutrients from the Leaves of Water
Hyacinth Plant 5-18-76
Philippines Patent—Pending
U.S.A. Patent—Pending
Japan Patent—Pending
17. Invention Recycled Process of Particle Board
Manufacture from the Water Hya-
cynth Parenchyma

- | | |
|-------------|----------------|
| Philippines | Patent—Pending |
| U.S.A. | Patent—Pending |
| Japan | Patent—Pending |
18. Invention Process of Producing Wine & Alcohol from Water Hyacinth Juice
- | | |
|---------------|----------------|
| Philippines | Patent—Pending |
| Brazil Patent | Patent—Pending |
| U.S.A. | Patent—Pending |
| Japan | Patent—Pending |
| West Germany | Patent—Pending |

CIVIC ACTIVITIES:

1. *President*
Filipino Inventors Society, Inc. 1976-77
2. *Executive Vice-President*
Philippine Chamber of Inventors & Technologists, Inc. 1976-77
3. *Director*
Institute for Small Scale Industries Alumni Association, Inc.
University of the Philippines 1975-76
4. *Director-Secretary*
Filipino Association of Rubber Manufacturers 1976-77
5. *Member*
Philippine Chamber of Industries
7. *Member*
United Inventors & Scientist of America
Los Angeles, U.S.A.
8. *Procell Member*
Development Academy of the Philippines
9. *President*
8th Managers Course
Institute for Small Scale Industries
University of the Philippines
10. *Honorary Life Member*
United Disabled Veterans Association
of the Philippines

LETTERS OF COMMENDATIONS:

Received from:

1. *Ramon Magsaysay*
Late President of the Philippines
2. *Chairman*
Senate Committee on Ways & Means
Republic of the Philippines
3. *Chairman*
Senate Committee on Commerce and Industry
Republic of the Philippines
4. *Chairman*
Senate Committee on Agriculture and Natural Resources
Republic of the Philippines
5. *Chairman*
Senate Committee on National Defense
Republic of the Philippines
6. *Chairman*
House Committee on Anti-Filipino Activities
Republic of the Philippines
7. *Chairman*
House Committee on Reparations.
Republic of the Philippines
8. *Chairman*
House Committee on Immigration
Republic of the Philippines
9. *Secretary Arturo Tanco, Jr.*
Department of Agriculture
10. *Hon. Edwin Edwards*
Governor, State of Louisiana, U.S.A.
11. *Filipino Inventors Society, Inc.*
12. *Philippine Chamber of Inventors & Technologists, Inc.*

APPENDIX B

EVALUATION OF HYACINTH PULP-BASED PAPER HANDSHEETS



Date September 8, 1976
To JL Otis
From TJ Collier *TJ.C.*
Subject Paper from Water Hyacinth, Bleached and Unbleached

Handsheet samples indicated the following on cursory examination, by hand and visual methods.

- (1) High tear strength.
- (2) Good stiffness.
- (3) Medium length, fine fibers.
- (4) Structure of sheet would indicate poor water drainage (freeness) on paper machine wire.
- (5) Samples, especially unbleached sample contained a large number of dirt particles.
- (6) Good wet strength. This sheet appeared to be highly sized internally. No ink feathering was noted. The sizing action could have been from residual materials left from the pulping operation (gums, etc.).
- (7) Formation of the sheet was fair. Better formation may be expected on a fourdrinier wire.
- (8) The sheets appeared to be uncalendered but heavily pressed.
- (9) The sheets were smooth on one side and knotty on the other. It is believed that the knots were caused by residual particles that could be screened out.
- (10) The bleached sheet was low brightness.
- (11) There is a parchment-like quality to the paper in its rattle toughness and appearance.
- (12) Opacity was low.
- (13) Very good to excellent tensile strength was noted when dry and good wet tensile strength was evident.
- (14) No filler was evident in the sheets.
- (15) The sheets were uncoated.
- (16) No odor of rosin was noted when the paper was heated.

It may be possible that the fibers in the papers have adherent gum that acts as a size and transparentizer for the sheet.

Possible uses for the hyacinth fibers and/or paper may be as follows:

- (1) Since the hyacinth fibers are fine and long, good printing surfaces combined with strength are achieved. The combination of hyacinth pulp and softwood kraft pulp may yield a food packaging board with superior smoothness, excellent printing characteristics and reasonable drainage on the paper machine.

Memorandum

2

September 8, 1976

- (2) Papetries could be an application for hyacinth paper because of the parchment-like qualities that are observed in the samples.
- (3) Specialty applications may be possible, such as filters.

The above observations and ideas resulted from my examination of two small samples of paper made in a handsheet mold, one of bleached, the other of unbleached water hyacinth pulp.

TJC:dwh



Date October 29, 1976

To J. L. Otis *J. C.*

From T. J. Collier

Subject Paper from Water Hyacinth

Further to my memo of September 8, 1976, I have the following comments.

Two additional samples of handsheets made from water hyacinth pulp, identified as Stem Fiber Paper - Unbleached - Waterlily Soda 4646,5, March 3, 1976 and Parenchyma Paper - Unbleached, were examined. The unbleached stem fiber paper showed only one characteristic different from those observed and noted in my September 8, 1976 memo. An odor similar to that of styrene-butadiene latex was noted when the unbleached stem fiber sample was heated. (This odor might be attributable to either residual material from prior non-hyacinth trials, or decomposition of a natural organic material in the unbleached hyacinth Pulp).

The parenchyma sheet was found to be entirely different in character from the stem fiber sheet. It shows the following by cursory examination.

- o Low tear strength
- o Good stiffness
- o Short fiber length
- o Poor fold
- o Very dark in color. It appears to be full of resinous residue, resembling lignin.
- o Fair to poor wet strength
- o Sheet formation is fair
- o Opacity is high due to brown color
- o The sheet blisters badly when heated.

Both of the sheets were flat, and not rolled or wrinkled.

The indicated high tensile strength of the Stem Fiber Paper are at odds with the conclusion drawn by the University of Florida examination.

If the parenchyma and stem fiber pulps were pulped together, the consumption of cooking chemicals would be high due to the observed resinous material in the parenchyma. Separation of the parenchyma from the stem fiber would alleviate this condition.

I believe the negative characteristics found at the University of Florida were caused by the inclusion of parenchyma in the sheets tested, thus yielding ~~brittle sheets~~, dark color, poor tear properties and poor tensile and burst properties.

To: J. L. Otis
From: T. J. Collier

2

October 29, 1976

The parenchyma pulp, due to the high resinous character could conceivably make a material similar to vulcanized fiber be made into a hardboard.

The high fold and tensile strength of the Stem Fiber Paper are also those properties needed in currency papers.

TRS:dps